

POTS EXTENDER FOR VOICE FALLBACK IN A SUBSCRIBER LINE
FIELD OF THE INVENTION

[0001] The invention relates to broadband access methods and more particularly to providing a network-side surrogate when an access device is impacted by a fault.

BACKGROUND OF THE INVENTION

[0002] Current voice telephone system operators are generally engaging in a growth phase of deploying data services to their subscribers. One of the chief ways to do this is to offer digital subscriber lines (DSL) wherein both voice and data may be carried over a common twisted pair cable to a subscriber's residence or business. In one of the more popular versions of DSL, Asymmetric Digital Subscriber Line (ADSL), a twisted pair carries two types of duplexed signals over different frequency bands. The first signal is the voice signal, generally at 4 KHz and below. The second signal is the data signal, generally modulated at above 4KHz.

[0003] Other forms of DSL may inter-mingle voice signals with data, by, e.g. voice over packet (VOP). Such forms include: Symmetric DSL (SDSL), High bit-rate DSL (HDSL), and Very-high-bit-rate DSL (VDSL). In such cases, the voice signal may be modified by a Integrated Access Device (IAD) to be converted into data packets. A IAD is intended to provide access to the twisted pair by multiplexing at least one voice signal with other signals, such as data, which is used most commonly by computers for internet access.. Such a device, coupled with DSL service can provide a great improvement to home-owners or small businesses because the cost to maintain a single twisted pair subscriber line that multiplexes various signals is much less than having a dedicated subscriber line for each device at the customer premises.

[0004] Unfortunately, because the IAD is performing high level communications functions -- essentially changing the signaling format between dissimilar networks -- the IAD may be susceptible to power failures that leave none of the customer premises equipment operating. Although the data culture associated with computers has long accepted, in many situations, the possibility of intermittent failures, the opposite is true for the voice telephony world. Namely, in many parts of the world, a telephone is viewed as a necessity, and particularly, a valuable tool to avert disasters through timely call placement to emergency personnel, e.g. calling 911. For this reason, telephone switches are required to have an up time greater than 99.999% of the time.

[0005] Thus the dilemma: how to offer fast data throughput, including that supporting voice, and maintain constant fault-free voice operation to a customer while keeping the number of subscriber lines between customer premises and data aggregator to a minimum.

5 [0006] Part of the solution lies in the ability to adjust the operation of a remote device, by transmitting a minimalist signal from the local device that is failing -- a last gasp, if you will. A signal may be the encoding of two or more values (sometimes voltages) that change over time on a medium. A packet may be a series of changing values or an arrangement of signals. A protocol may involve
10 the exchange of one series of changes on a medium. A signal may occur when a voltage changes or where an established protocol requires a responsive reply, but none occurs. Under ordinary circumstances a master DSL master modem communicates with a slave DSL modem component of the IAD so that the slave DSL modem synchronizes or trains to signals provided by the master DSL. Any
15 failure of the slave DSL modem to respond under this protocol may be taken as a signal that the slave DSL is in a fault mode.

[0007] A data aggregator may be a Digital Subscriber Line Access Multiplexer (DSLAM) having at least one master DSL modem. Constant voice access has been accomplished for some forms of DSL by providing a secondary twisted pair
20 line between a data aggregator and an IAD. Companies such as Coppercom provide a IAD that upon detecting a power failure, would route at least one of the telephones at a customer premises to the secondary twisted pair line -- thus bypassing the data network altogether. For obvious reasons, it is twice as costly to maintain the two pairs of cabling from the data aggregator such as a switch or a
25 DSLAM to the subscriber than in the situation where a single twisted pair is used. Nevertheless, the highly fault-resistant voice central office is much more reliably available than its counterpart, the IAD. This is true because central office (CO) equipment is more capable of providing reliability because of economies of scale, particularly due to CO backup batteries and other redundant power sources.
30 Thus, there is a need to extend plain old telephone service (POTS) to an IAD that has failed in that the IAD is unable to transmit data packets.

SUMMARY OF THE INVENTION

[0008] Embodiments of the invention may provide a switch-over means at a data aggregator and other network elements when an integrated access device
35 (IAD) is unable to transmit packets. Such a switchover may be accomplished in part by a detector that identifies the presence of analog signals on the subscriber

line connecting the IAD to the data aggregator. Upon detecting such analog signal carrying e.g. voice frequencies, the data aggregator, according to the embodiments, may disable any DSL modem present at the data aggregator, and couple an analog to digital converter to prepare signals arriving on the subscriber line for transmission on a data network. Other devices such as a vocoder and packet assembler and disassembler may complete the conversion of the formerly analog signals for packet transmission through the data network. This accomplishes a couple of things. Continued telephone service may be maintained to a customer premises even though an IAD has a power failure -- and this without the need for a dedicated backup analog subscriber line in addition to the subscriber line that carries digital packets. Consistent with the continued telephone service is the provision, at a central point, of power to the remote customer premise equipment, thus providing economies of scale that may be available where multiple diverse customer premises may need power back-up, and the power back-up is collectively provided at the data aggregator.

[0009] An embodiment may provide a fallback mode to a subscriber line. A POTS extender, which may convert a upstream voice signal on the subscriber line to at least one upstream packet. Similarly the embodiment may convert a downstream packet on a packet network to a downstream voice signal.

[0010] The embodiment may have a subscriber line interface circuit (SLIC) connected to the subscriber line. A codec converts signals from the SLIC to an upstream digitized voice signal output. The codec also converts signals from a vocoder to downstream voice signals. A vocoder converts voice signals to datastreams in both the upstream and downstream directions. A packet assembler and disassembler (PAD) may convert the first data stream to at least one packet. The PAD may convert at least one packet into the second data stream, wherein the PAD is coupled to the packet network. The PAD may have at least one network address. The embodiment may include an output means for transmitting a Master Digital Subscriber Line modem control signal.

[0011] Another embodiment may include a digital subscriber line (DSL) suppression circuit for suppressing DSL modem operation on a subscriber line. The embodiment may have a subscriber line interface circuit (SLIC) for sensing current drain on the subscriber line. A means for providing a suppression signal may connect to the SLIC and a master DSL modem may operate coupled to the SLIC, said master DSL modem operating in a quiescent state upon receiving the suppression signal.

[0012] In the end, at least one embodiment may place a master DSL modem

in a quiescent mode whereby voice traffic may operate on the subscriber line without any modulation by a master DSL modem interfering.

BRIEF DESCRIPTION OF THE DRAWINGS

[00013] Fig. 1a shows an architecture supporting voice over packet protocol according to an embodiment;

[00014] Fig. 1b shows a comparison of two architectures supporting voice over packet protocol;

[00015] Fig. 2 shows a block diagram of a Integrated Access Device (IAD) according to an embodiment of the invention; and

[00016] Fig. 3 shows a block diagram of a Full Services Access Multiplexer (FSAM) according to an embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[00017] Fig. 1a shows an architecture supporting voice over packet protocol **100** including Integrated Access Devices (IADs) and data aggregators. The data aggregator may comprise a Digital Subscriber Line Access Multiplexer (DSLAM) **101** having a Full Services Access Multiplexer (FSAM) embodiment attached to at least one local loop **103**. A DSLAM is typically located at a central office and may interconnect voice packets of a subscriber line to a switch via circuit switched connection. In addition, the DSLAM may interconnect voice packets on a subscriber line to a packet network using Asynchronous Transfer Mode (ATM) and other network protocols. The FSAM terminates the local loop **103** that is served by an IAD **105**. The IAD **105** may be located at the customer premises.

[00018] The IAD **105** may multiplex multiple terminals and may serve both an analog voice terminal **107** and a data terminal **109**. In the case that the terminal is a voice terminal, the IAD **105** may provide, among other services, conversion of voice and other analog signals to digital encoding; packetizing such encoding into packets; and addressing such packets according to conventional packet protocols. Other functions consistent with voice over Packet (VoP) may be provided by the IAD **105**, including providing signals of call progress over the analog line **111** at the customer premises, wherein the analog line is a customer premise line.

[00019] Fig. 1b shows two example configurations of Fig 1.a that include a data aggregator. In the first configuration, a voice terminal **145** connects to an IAD **105**, which provides access to a subscriber loop **150**. A data aggregator **101** may place signals arriving by subscriber loop **150** onto a data network **152**. A concentrator **155**, which may be compliant to GR-303 standards, concentrates signals with traffic arriving from other sources. A switch, e.g. a class 5 central

office **157**, may route signals to one or more other voice terminals in a network, which includes the public switched telephone network (PSTN).

[00020] In a second configuration, a data aggregator **101** may receive such packets or analog signals over the subscriber loop **150** and route the packets or analog signals according to commands given by a softswitch **173**. The softswitch **173** may direct such packets to one or more gateways **175**. Such commands, or signaling, may pass over a data network **115** capable of transmitting and routing packets, e.g. the Internet.

[00021] In both configurations the data network **152** of the first configuration, and the data network **115** of the second configuration may provide a medium for receiving requests for service originating at the voice terminal **145** and **165** and controlled by the concentrator **155** or softswitch **173**.

[00022] The data network **152** and **115** may operate cooperatively with the concentrator **155** or softswitch **173** and other network elements to perform call processing, billing and other functions related to transmission of voice traffic over a data network. A service provider may own or operate edge nodes of the data network **115** and secure agreements from owners or operators of neighboring nodes to assure continuing availability of packet transmission facilities. Since the operation of data networks such as the internet are known to have many levels of redundancy, traffic that reaches the network is virtually assured safe passage to a destination. Similarly, it is known that the data network may transmit a greater bandwidth with lower costs than may be accomplished in a more conventional circuit switched telephone network. The reliability and bandwidth of the internet is accomplished through the use of many redundant paths for transmission of data signals and control signals.

[00023] Even though the local loop **103** of Fig. 1a is without a redundant spare, the operation of the IAD **105** tends to be more failure prone -- particularly due to transient power availability, including blackouts. The IAD may be provided with a kind of redundancy -- and greatly improve the overall capability to reach the network for voice transmission purposes, even though data handling may be hampered by unavailable power.

[00024] Thus, an IAD **105** according to an embodiment of the invention, may provide an IAD fallback signal in the local loop **103** to signal to the data aggregator **101** that the IAD **105** is operating in a fault mode, caused by, among other things, local power failure at the IAD **105**. The IAD **105** may operate passively, wherein either it fails to respond to packets that request a response, or the IAD **105** fails to provide a follow-up signal during a time-out expiration. In any event, the absence

of signals from the IAD **105**, itself, is a signal that the IAD **105** is in a fault mode. The data aggregator **101** according to the embodiment, may adjust accordingly by refusing to pass along any data packets over the local loop **103** until the IAD **105** restores the packet transmission support to the local loop **103**. The restoration of packet transmission support may be signaled by a IAD-restore signal dispatched by the IAD **105** onto the local loop **103**. Such an IAD-restore signal may be part of the start-up handshake between a slave DSL modem **106** and a master DSL modem **126**, such as synchronization signaling.

[00025] Fig. 2 shows the internal operation of an IAD **105** according to an embodiment of the invention having a switching means to bypass packet-transmitting circuits. At least one voice conductor pair **201** dedicated to a voice terminal, e.g. a conventional wired telephone, enter the IAD **105**. The architecture of the embodiment may function adequately without the embodiment of Fig. 2.

[00026] In an unpowered situation, a relay **203b** or other switching means provides a straight through connection between a voice terminal **205** and the data aggregator through the local loop **207**. Upon applying power to the IAD **105**, the central processing unit (CPU) **209** may do self testing, verify operation of IAD components, configure IP addresses and other activities of an IAD **105** necessary to route packets with correct headers and provide signaling functions. One or more of the foregoing steps occurs during a process called boot-up, or the step of booting up the processor. Upon completion of the boot-up, the CPU **209** may energize the relay **203a** to switch in a vocoder **211** and a packet assembler and disassembler (PAD) **213**. The vocoder **211** may receive signals from the individual voice terminals **205** by way of a bank of SLICs **210**, which may provide basic power to each line **201**, among other signals. The bank of SLICs **210** may provide at least one upstream signal to codec **212**, wherein the codec **212** may provide an analog to digital conversion such that vocoder **211** receives digital signals. Similarly, codec **212** may convert digital signals received from the vocoder **211** to analog signals directed to the bank of SLICs **210**. Vocoder **211** may be a G.711 variety of vocoder. Alternatively, the vocoder **211** may provide compression to upstream signals and decompression to downstream signals using, e.g. G.726 algorithms. The state describing the IAD **105** upon the application of power and completion of boot-up is called the vocoder mode. Failure of power restores the relay **203** to its former condition, providing a straight-through connection between the voice terminal **205** and the local loop **207**. This state is called the bypass mode.

[00027] Additional telephones may be attached to the IAD **105** through ports

that connect voice either directly to the local loop **207** or to the bank of SLICs **211** depending on the operating mode. For each telephone that is connected via the vocoder **211** through a distinct port, a network address may be assigned. The address assignments may be made via a local man-machine interface or by remote control, perhaps using the packet network to carry the instructions. The addresses may be IP addresses and port pair combinations or Asynchronous Transfer Mode (ATM) Virtual Circuit (VC)/Virtual Path (VP) pair identifiers. Thus the IAD **105** inherently may have the capability to present to the network (at the subscriber line) multiple virtual circuit identifiers for so long as power is supplied to properly functioning IAD **105**. Storage of the address assignments may be in a local non-volatile memory to the IAD **105**. Unused ports may be jumpered by a short conductor. Additional packet ports **240** may provide an interface to the PAD **213** while power is available and the relays **203** are in the vocoder mode position. Similarly, one or more data streams may be sent upstream from vocoder **211** to PAD **213** for proper packet formatting and addressing. DSL modem **257** may provide physical layer support for packets bound from PAD **213** to the upstream data aggregator on the local loop **207**.

[00028] The relay **203** may switch telephony ports **230** so that while the IAD **105** is in the bypass mode, all telephony equipment including facsimile equipment, are in the same circuit, commonly referred to as a party line. The operation of the relay **203**, may change the character of the local loop, by e.g. disabling the origination of data packets from the IAD **105**, while in bypass mode. Similarly, the IAD **105** may lose the ability to associate a voice circuit and other addressing of the various telephony equipment. Some other device in the data network must take on that job in order for a voice call to be routed over the data network, i.e. a device upstream from the IAD **105** must adopt this function, otherwise the local telephones will be unable to make emergency calls. In other words, a FSAM embodiment of the invention may provide a voice circuit association to the local loop **207**, among other functions.

[00029] The detection of an off-hook condition of one or more of the telephones may be a preliminary test done by the CPU **209** following boot-up. The CPU **209** may periodically retest the line, if an off-hook condition has been detected, until all telephones connected to the IAD **105** are on-hook. Following power restoration, a boot-up and any off-hook period, the CPU **209** may energize the relay **203** to operate in a vocoder mode such that the vocoder **211** and the PAD **213** provide packet traffic to and from the local loop **207**. At that time, IAD **105** may multiplex and voice traffic and data traffic from local telephones and data sources on the

local loop **207**.

[00030] Fig. 3 shows a parallel configuration of a Full Service Access Multiplexer (FSAM) **315** comprised of a plain old telephone service (POTS) extender **301** and a master DSL modem **303** at the data aggregator, or FSAM.

5 The POTS extender **301** may be a POTS extender, wherein POTS service is supported at a voice terminal through to the FSAM **315**. The FSAM **315** may occupy two slots in a frame of equipment wherein one slot is filled with the POTS extender **301** and another slot is a master DSL modem **303**. The frame of equipment may house other FSAMs and master DSL modems to service local

10 loops to other subscribers. The frame of equipment may be homogeneous in the sense that all master DSL modems are slaved to at least one POTS extender. The frame of equipment may be heterogeneous in that not all local loops are terminated by a FSAM. Some local loops have no support for emergency fallback because a legacy master DSL modem terminates the local loop that is not

15 controlled by an FSAM embodiment of the invention or other life-line supporting apparatus.

[00031] Under ordinary circumstances where the master DSL modem **303** is in active communication with the IAD **105**, or while the master DSL modem **303** is training the IAD **105**, the master DSL modem **303** may be said to be in an active

20 state. In this state, the master DSL modem may provide at least one voice path (VP) or other address at the backplane **307** which corresponds to at least one telephony device at the IAD **105**.

[00032] The frame may provide an aggregating unit, such as a multiplexer or a router, to combine the traffic arriving at several FSAMs onto a common, high-

25 bandwidth, trunk line. Such traffic may include upstream voice packets. Similarly, the multiplexer or router may provide downstream voice packets addressed to at least one FSAM. The frame may provide redundant trunk lines, to better assure a path to a data network, such as the Internet. In addition, load balancing, and other algorithms to distribute traffic, may be employed while sending traffic to the data

30 network, as is known in the art.

[00033] The POTS extender **301** may have a connection to the tip of the local loop **309** in common with a master DSL modem **303**. The POTS extender **301** may have a connection to the ring of the local loop **309** in common with the master DSL modem **303**. The POTS extender **301** may have a control circuit **305** to the

35 master DSL modem **303**. Alternate ways to send a control signal from POTS extender **301** include transmitting such a signal through a backplane **307**. Such a control circuit may be under programmed control of a CPU **331**. POTS extender

301 may control the operation of the master DSL modem **303**, such as, by sending a suppression signal or master DSL modem control signal to the master DSL modem **303** to suppress attempts to synchronize with an IAD **105** and enter a quiescent state. The SLIC **311** may sense a current drain in the subscriber line **309** which indicates that the IAD **105** has closed relays that put remote telephones directly on the subscriber line **309** circuit. The master DSL modem **303** may enter quiescent state by means known in the art, including removing power to the master DSL modem circuits in response to a suppression signal arriving at the master DSL modem **303**.

[00034] The POTS extender **301** may have a number of circuits that permit it to support call-processing functionality. A Subscriber Line Interface Circuit (SLIC) **311** may provide loop current, electrical terminating characteristics, e.g. impedance, switch hook detection, and a ringing source as well as power the subscriber line **309** under certain conditions, such as operation in fallback mode. Switch hook detection may be provided by a switch hook detector coupled to the subscriber line **309**. DTMF tones and call progress tones including dial tones may be provided by the vocoder **351** in response to signaling provided by a gateway or a concentrator. The SLIC **311** may provide a switch hook detector. In some systems, an off-hook state of the switch hook may be detected based on current drain in the twisted pair as is known in the art, thus indirectly sensing an off-hook condition of a voice terminal. The master DSL modem **303** may detect synchronization.

[00035] There is a co-ordination function between the POTS extender **301** and the master DSL **303**, which may be transmitted over the control circuit **305**. Ordinarily, the POTS extender **301** may operate in a passive or quiescent state, wherein the POTS extender **301** may monitor the subscriber line **309**. In this state, the POTS extender **301** may not respond to packets that are addressed via the backplane **307** to an address that it may have in common with the master DSL modem **303**. In other words, the POTS extender **301**, while in the quiescent state, may provide no bridging function between the backplane **307** and the subscriber line **309**.

[00036] An IAD fallback signal may be provided by the IAD **105** in several ways. One way is that the IAD **105** may fail to respond to synchronization signals sent by the master DSL modem **303**. Another way is that the IAD **105** may fail to provide a data packet on the subscriber line within a time schedule established by a communications protocol for which it is designed to adhere. In any event, the IAD **105** begins to perform out of conformance with a protocol it has established

with an upstream device, which is detectable by the POTS extender **301**, which supervises or monitors the subscriber line **309**. When a subscriber line or local loop **309** IAD fallback signal is detected, master DSL modem **303** synchronization and data transmit functions may be suppressed by control signals sent from the POTS extender **301** to the master DSL modem **303** over connection **305**. Single circuit gateway **301** may then operate to interface the subscriber line **309** to the backplane **307**, which may be multiplexed onto one or more trunk lines. Single circuit gateway **301** may operate a single voice path (VP) and a single voice circuit (VC) during operation in fallback mode. The single voice path may be associated with a lowest telephone number assigned to the at least one telephony terminals at the customer premises. Thus call setup, as may be controlled by a softswitch or a concentrator, may occur normally for calls to that voice path. Only calls from that voice path may traverse the subscriber line **309** during the fallback mode.

[00037] Referring to figs 2 and 3, recovery from the fall-back may occur by sensing the subscriber line with loop current detector **255**. Before power is provided to the IAD **105**, the relay **203** is held in the bypass position, as shown in Fig. 2. When power is provided, CPU **209** may boot up. A program may be run on the CPU **209** wherein a test of any voice device **205** is made, wherein a determination is made if the voice device is off-hook. Off-hook voice devices will be detectable by loop current detector **255**. When the CPU **209** is running and such a program detects that all voice devices **205** are on-hook, two additional steps may be performed. The relay **203** may be energized, placing each voice conductor pair **201** in electrical contact with the bank of SLICs **210**, while placing the DSL modem **257** in electrical contact with the subscriber line **207**. An additional step may include enabling training by the slave DSL modem **257** so that the slave DSL modem and the master DSL modem **303** may be synchronized.

[00038] When an IAD-restore signal is detected by the POTS extender **301** on the subscriber line **309**, the POTS extender **301** may stop responding to any the voice path (VP) established during the IAD fallback. The POTS extender **301** may end suppression of the master DSL modem **303**, by sending a master DSL modem control signal, thus permitting normal synchronization of the master DSL modem **303** with the IAD **105**. The master DSL modem control signal may be one of two kinds: a signal to activate, meaning that the master DSL modem should attempt synchronization; and a signal to suppress, meaning that the master DSL modem should stop synchronization. Where multiple telephony ports of the IAD **105** are connected to telephony equipment, the IAD **105** may supply the voice paths (VP) and other addresses to each telephony port.

[00039] Thus, in fallback mode, the FSAM **315** may accomplish two things.

First, provide an analog port to the customer premises equipment or IAD **105**, wherein the IAD **105** may interface to the data network unimpaired by operation of any DSL modem on the circuit. Attendant with providing the analog port, the FSAM may provide a telephony current source. The current source may be used to power a remote telephone apparatus when off-hook, as is known in the art. In addition, Subscriber Line Interface Circuit (SLIC) **311** may interconnect a ringing signal source to the subscriber line **309** when an incoming call appears as received packets from the backplane **307**.

[00040] A second function of the fallback mode is that the FSAM **315** may provide a VP visible on the data network corresponding to at least one telephony port of the IAD **105**. A Subscriber Line Interface Circuit (SLIC) **311** may perform additional functions that enable call processing. The SLIC **311** may detect an on-hook condition by means known in the art. The SLIC **311** may detect an off-hook condition. These functions may include the provision of, ringing voltages, interconnect to battery or ring voltages, switch-hook detection and impedance matching. In addition, the FSAM **315** may convert analog traffic from the subscriber loop **309** to packets for transmission on the packet network, wherein the packets may be ATM (Asynchronous Transfer Mode) cells. The POTS extender **301** may provide a codec **345** interconnect to the subscriber line **309**, wherein the codec **345** performs analog to digital conversion of signals from the SLIC **311** to provide upstream digital voice signal. Similarly, codec **345** may convert digital signals received from the vocoder **351** to a downstream digital voice signal directed to the SLIC **311**. Data output **321** from the vocoder **351**, now a stream of bits, may be packetized by a PAD **353** for transmission on a broadband media. A connector **390** or other interface may link the PAD **353** to a backplane **307** having interconnect to broadband media, including those supporting T1, ISDN, and OC3 among others known in the art. Each of said functional blocks, vocoder **351** and PAD **353** may be performed by a DSP or a CPU operating alone or together.

[00041] A reverse process may occur wherein the PAD **353** receives downstream voice packets addressed to it from the backplane **307** and assembles the downstream voice packets into a data stream for a vocoder **351**. Vocoder may convert the data stream to a format amenable to digital to analog conversion. Codec **345** may perform the digital to analog conversion and provide the analog voice frequency signals to an input of the SLIC **311**.

[00042] Although the invention has been described in the context of particular

embodiments, various alternative embodiments are possible. Thus, while the invention has been particularly shown and described with respect to specific embodiments thereof, it will be understood by those skilled in the art that changes in form and configuration may be made therein without departing from the scope and spirit of the invention.

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